Stars Problem Set
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1 Stellar structure

1. Show that stars will be perfect spheres if self-gravity is the only force acting on the star.

2. In general stars are not perfect spheres, but are better represented as tri-axial ellipsoids, where 2 of the axes are along the stellar equator, and one directed along the spin axis of the star. Which of the axes of the ellipsoid will be shortest, and why?

3. When we say a star is a perfect sphere, we're really talking about the shape of the star's photosphere, i.e. the place where the optical depth = 1 at some conventional wavelength. Recall that the optical depth τ is given by
$$\tau = \int k dz \tag{1}$$
where k is the opacity, i.e. a measure of how efficient the material is at absorbing radiation. In the case of a spherical star, what is the dependence of the optical depth in the stellar atmosphere as a function of stellar latitude and longitude, if the opacity is a function solely of the local temperature T, i.e. $k = k(T)$.

4. If a star is an *ellipsoid* and the opacity of the atmosphere varies as T, where T is the local temperature, is the opacity greatest at the stellar equator or at the stellar pole?

2 Stellar Winds

1. Assume that an amount of matter M is carried from the photosphere from an O type star each second by a spherically symmetric stellar wind. If the wind velocity is a function of the distance r from the star, i.e. $V = V(r)$, show that the mass density ρ at any point r from the star is given by
$$\rho = \frac{\dot{M}}{4\pi r^2 V(r)} \tag{2}$$
where $\dot{M}$ is the mass loss rate

2. if the wind is entirely composed of H, calculate the particle density from the mass density in terms of $\dot{M}$, $V(r)$, r and the mass of hydrogen.

3. Write an integral expression for the column density N_H through the wind in terms of $\dot{M}$, $V(r)$, r and the mass of hydrogen.

4. Assume there is an X-ray emitting shell of gas at radius R from the star. Draw a diagram indicating the stellar photosphere, the X-ray shell, and the path along which N_H is calculated.

3 The HRD

1. Draw a schematic HR diagram, indicating the directions of increasing temperature and increasing stellar luminosity. Indicate the location of the main sequence, and show the locations of a bright cool star and a faint hot star, neither of which is on the main sequence.

2. Indicate the evolutionary path of a 50 solar mass star in the theoretical HRD from birth to death, labeling the star's location at the start of H burning, at the end of H burning, and when the Fe core forms.

3. Indicate the evolutionary path of a one solar-mass star in the theoretical HRDfrom birth to death, labeling the star's location at the start of H burning, at the end of H burning, at the start of He burning, and the star's final resting place.